

A review of keyboarding skills

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We may analyse keyboarding in elements and evaluate the relative importance of the component parts of this particular skill. This may help in assessing the requirements of operators, methods of training and how the work can be made easier by modifying technical aspects of the interaction between men and machines.

The next stage will be to translate these suggestions into testable hypotheses, and when the results of the relevant experiments are known, we can, on the basis of our findings, advise management, constructors of apparatus, training instructors and indeed the operators themselves.

In a skill like keyboarding there are some basic operations which, given proper instruction, are learned very easily, but after this first improvement progress becomes much slower, with periods of an apparent standstill. The necessary movements will become integrated. We will take a more analytical approach since we do not precisely know how accurate these statements are.

Most psychologists will agree that a definition of skill involves the building up of spatially and temporally ordered units of perception and corresponding responses according to an ideal pattern. (See Ammons, et.al. 1958. Fitts 1964, Bartlett 1958, Miller et.al. 1960.) A generalized image of how the job should be done is developed. The checking of the difference between this ideal and the actual results will help in improving the performance.

In considering how this perception of incoming signals or stimuli works, how it is related to the operations that have to be executed, what the feedback is and how the general improvement in skill comes about, the problem is rather complicated as we have to discriminate two dimensions. On the one hand, the role and importance of learning and on the other, the mutual integration of the different components like perception, memory, motor activities into a simple structure.

We will give a schematic representation of the components which are important in keyboarding. We will know that we have covered all relevant elements, when we find no significant change in the performance as long as we keep the defined variables constant. The importance of a variable, like feedback, depends upon the amount of change in the system, for example decrease in output, brought about by a controlled varying of this variable. In this way we can evaluate each variable by systematically varying it while keeping the others constant, and observing the output of operators. (cf. Ross Ashby, 1952.)

Long-term storage

The basic problem is how our past experience is stored and mediates in the different elements of the keyboarding process, as well as how it facilitates the interaction between the inherent human dispositions and capacities and the requirements of the task.

Lately there has been a revival of studies to test the hypothesis that the frequency of stimuli in the environment is negatively related to the latency of responses to these stimuli. (Oldfield & Wingfield, 1966—Fisher & Bowles, 1966.) When we consider the use of language as a highly developed skill, this may be the only skill where it is possible to obtain nearly correct estimates of the number of times that each different word has reached our sense organs and is stored in our memory. These estimates are given in such word counts as those of Thorndike and Lorge in 1944 and the recent ones on a more extensive and representative sample, by Fisher, 1966. It is a very important finding that the more frequently a word is used in the language, the shorter the time taken to find an appropriate word to describe the picture.

To explain the differential latency time in relation to the varying previous frequency of stimuli, we postulate the operation of a continuously active, long-term memory storage, within which previously encountered items are to be found.

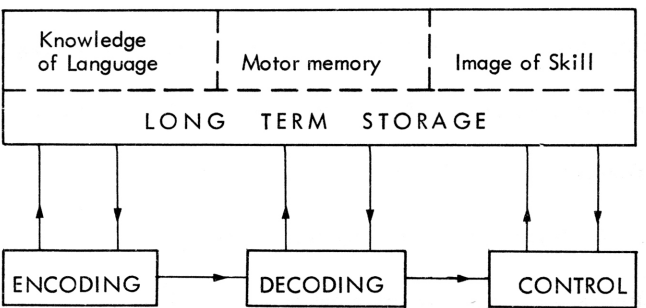


Fig 1 Schematic representation of the long-term storage, superimposed over the component parts of the skill of keyboarding

This store of experiences is built up in everyday confrontations with the environment as perceived and responded to by the subject. Every incident will increase the precision of the subjective probability of that stimulus coming again, and the nature of organization of this memory-store will facilitate the anticipation of stimulus-response sequences and reduce the uncertainty over the number of possible responses given to a certain stimulus. The mechanism is superimposed, therefore, over the entire process of perceiving, responding and controlling. It is possible to

distinguish in the long-term store, three intermingled parts, each corresponding vaguely to one of the components in keyboarding, namely knowledge of language, motor memory and image of the skill.

As to the question of how exactly our experience is stored in the form of memory and influences recognition and the resulting behaviour, an acceptable guess (Rosenblatt 1958) is that retention takes the form of new neurological pathways or connections between centres of activity in the brain.

An example: Seeing the letter A activates a set of brain cells. When key A is sought and pressed, a different set of brain cells is activated as well as connections between the perceptual and motor sets of cortical cells. So we can say that the preference for a particular response is built up and stored. Subsequent stimuli will make use of these pathways which have been created, automatically activating the appropriate response.

We can give now, in the next diagram, a more detailed schematic model of the processes and elements involved in the skill of keyboarding. We will discuss successively 1. The input, 2. Encoding with storage, 3. Translation, 4. Decoding and finally, 5. The feedback of the output, indicating for each part its relevance to the actual work of a compositor and its relationship with the long-term storage.

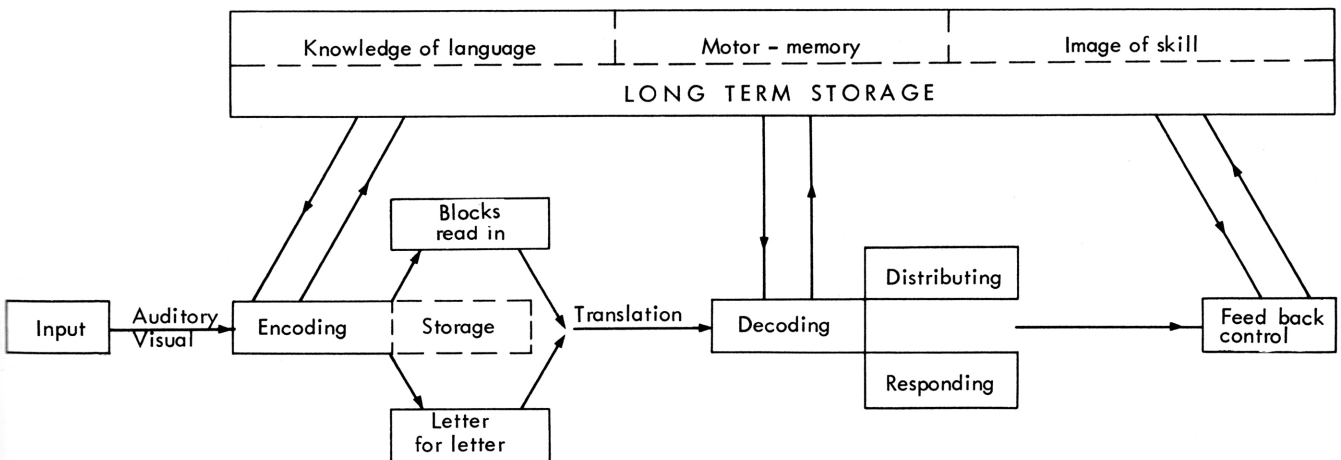


Fig 2 A review of keyboarding skills. This chart shows the components into which we have analysed the skill of keyboarding. Note the continuous two-way interaction between the process itself and the long-term storage which accounts for the improvement with practice. Two possible methods of encoding are distinguished. By 'control' is meant the correction of errors and shortcomings in the performance.

Input

Information, ideas, in general anything that has to be communicated in printed form, has to emerge letter by letter, perhaps, in the future, word by word. In this ordered 'funneling' we do not foresee revolutionary changes that will make the human operator redundant. This splitting up in letters and ordering is in fact his essential role in the typesetting process.

The copy is a continuous flow of symbols. It can be in a spoken or written form. This form determines the sense-channels to be used in perceiving or encoding. The main difference between spoken and written copy is that in the first case the typing speed required is set by, say, a tape recorder and in the second by the operator himself.

We do not know of research that has analysed how the operator exactly proceeds. Does he read a line and then dictate it to himself letter by letter? Further questions are: Is copy on a tape easier than copy written out? Should the spoken copy be dictated in sentences, word for word, or perhaps letter for letter? And when the technique reaches a stage where a spoken word or letter can be translated to an impulse that uniquely types out the required word, what will be the efficiency, the freedom from errors, the stress imposed on the 'dictator' and what training will be necessary? Research is needed on all these questions.

Although there are 26 different letters to be perceived in the input, they are not ordered at random. There is a high degree of redundancy in conventional English. The uncertainty as to which letter comes next is progressively reduced; first some letters are more frequent than others, secondly the probability that a given letter like 'T' is followed by an 'H' is quite high, thirdly in the word itself and its meaningful context in the sentence the next letter may be inferred from familiarity with the language.

In the past 15 years, concepts derived from information theory have been introduced in psychology. The human being, engaged in encoding and decoding functions, can be seen as a channel along which information is processed. This channel is subject to noise and distortion and is supposed to have only a limited capacity. This means that in a given unit of time only a limited number of equiprobable alternatives can be processed. If the information surpasses this critical quantity, then the input will be more extensive than the output and some of the information will be lost. A description of keyboarding according to this model is indeed very useful, as it enables us to specify a quantification of the input, the transmission and the output in mathematical terms.

As to the quality of the copy, we can say that bad copy, noise, not necessarily auditory but visual too, diminishes the discriminability of the proper signals, ie makes it difficult if not impossible

to identify them by hearing or reading. The probability of an error is proportional to the number of possible alternative solutions, the acceptability of which is determined by how closely they fit the context, or how closely the symbol plus noise resembles any other symbol which has been typed before. An appeal is, therefore, made to the memory.

Encoding

This term covers the process of taking in copy, visually or auditory, and keeping this information for a very short period in a store after some recoding or rearranging. As learning proceeds, this encoding will become better adapted to the probabilities associated with the sequences of stimuli, so that the integration with the resulting action can become more efficient (Fitts 1964). It is obvious that the typists acquire training in this encoding throughout their life when reading books or newspapers, so it is improbable that we will find here big differences between more and less experienced operators.

In the perception of letter sequences, there is an activation of brain cells with successive identification of elements, extracting meaning out of the context, and grasping of the significance for ensuing action (Welford 1958). In the more practised forms of encoding skills, the second stage, however, can be left aside and less conscious control is required.

The role of the long-term storage—the effect of past experience on present behaviour—in bringing about economy of effort, is rather complicated. We will deal rather extensively with its role in encoding as we believe that *mutatis mutandis* its influence is the same on the responding or decoding side of the process. In our analysis we will follow the excellent review of Welford, 1958.

When reading English as distinct from an unfamiliar language, say Chinese, there is a rough expectation of what will come. Certain categories of input are excluded. Apart from this expectancy or set, there is furthermore, as in listening to music, a continuous anticipating of what will come next, in that the sequential probabilities in the past will foreshadow the probability of things to come. The permanent storage will assist too in giving a meaning to sequences of letters, grouped in words and sentences, and will help in detecting errors by noting discrepancies between words in the memory and the given sequences.

This memory-based and hence improved reading results also in a saving of time as a great deal of detail is not perceived but inferred. Some errors will be detected and corrected. Furthermore the stress on the full conscious attention will be reduced. At the same time there is a refining and strengthening of the long-term store during the processing of the stimuli.

In our definition of encoding, we stated that the input is stored for a short period. What is read or heard is available for a period of some seconds without change or distortion. The mechanism to which this function is usually attributed is known as 'Short-term memory', as distinguished from the long-term storage. The

storage time is a matter of seconds and can be conceptualized as the time during which a sequence of symbols keeps activated a set of neurons or brain cells, so that this field can be scanned in any order, and the required information or instructions for sequences of movements can be extracted out of these symbols. (Compare Lashley 1951.)

The memory span—the number of symbols to be kept in this store without danger of being forgotten—may differ for auditory and visual input. Broadbent (1956) found that the presentation of information simultaneously to eye and ear gives at least as good retention as presenting all the information to one sense only. This finding may be of some importance for training. In general, the memory span is about 7 units (Miller 1956). We deliberately use the word units and not separate letters as the length of such a unit is determined by the degree of redundancy in the input sequence. With highly overlearned simple English it can consist of 7 words or even groups of words, while with random sequences of letters, it will consist of 5-9 characters, dependent on the number of alternative symbols (vis. 26 in English, 200+ in Chinese).

The operator has in this way a kind of preview of the sequential reactions he will have to make (Leonard 1953). By anticipatory timing he can initiate the correct order of the fingers to be moved as well as of the movements themselves before the actual occurrence of the stimulus, so that the reaction time is better than the optimal value that would have been expected, had the typist waited for a stimulus to occur and then responded to it as quickly as possible. (Adams 1964.)

We will now consider possible modes of extracting instructions for the successive movements out of this store. There are essentially two theoretical alternatives.

The *block-model*: A sequence of symbols (a line) is read in simultaneously at a glance and the required operations on this sequence are performed successively. Subsequently the next sequence (block) is read and processed. The eye-hand span extends over the length of the whole block.

The alternative *model of eye-hand co-ordination* is shown in the second diagram.

The *letter-by-letter model*: The input is read in stimulus by stimulus and is responded to successively with an initial delay of a number of symbols. This delay remains constant between the stimulus being perceived and the one that is being simultaneously keyed. Every time that a key is pressed the eye moves along one character (cf. Broadbent 1958).

We do not as yet know exactly how a given typesetter works in different stages of skill. We are convinced, however, that the two different strategies for processing implied above can be induced by training and we would not be surprised at all if a course of programmed training with verbal input, like the typing course given by 'Sight and Sound', results in the second method, and the traditional method of training in the first. The differences between these two models of processing have far-reaching

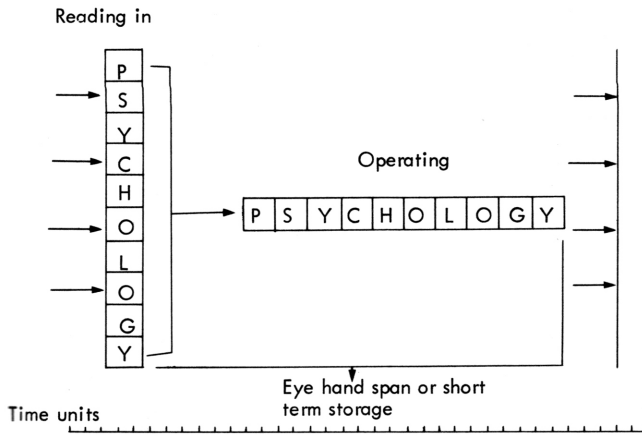


Fig 3 The block model for encoding of the input

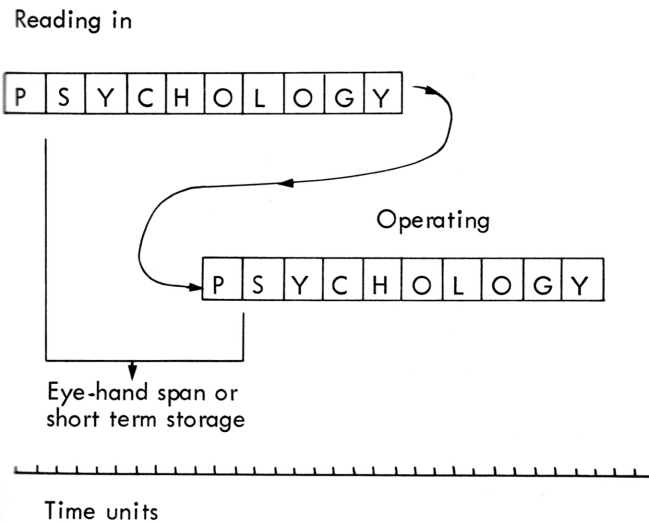


Fig 4 The letter by letter model for encoding of the input

consequences on the skill as a whole.

The eyes have to be kept on the copy. This means that control of the end of line, of hyphenation and of print-out is less effective and more disturbing. When the operator looks back at the copy to the last letter typed, he may select the wrong letter, whereas in the first system he will be more likely to recommence with the wrong word.

There is no recoding or rearranging of the input sequences and much shorter sequences of letters are kept in the short-term store. A favourable consequence is that the material is less distorted by errors caused by forgetting and also that in a shorter time of training a higher speed can be attained. Furthermore, the rhythm may be more regular and this results in less fatigue. An undesirable consequence is that no errors in the copy will be corrected and that it is more difficult to plan and anticipate the end of a line with long words.

The quality of the copy has to be better, as no errors will be corrected and symbols that are confusing cannot be inferred on the basis of meaning in the context, as the copy is read in letter by letter. There will, however, be no difference in speed or errors between typing of English, a foreign language or nonsense. In

typing there will be less 'sequential' errors where the sequence of letters is reversed, but there will be less detection of when the wrong key is struck. The consequences are that the highest increase in efficiency will be achieved when using this method of encoding on a machine without hard copy production where the tape is to be processed say by a computer. Additional feedback, for instance those concerning line-ends, however, should not occupy the visual channel, but would be better given by an audible warning.

The method will suit some operators better than others. It is possible that the letter by letter read-in will set an upper limit to the speed to be attained, but that the required training will be much shorter.

Additional problems are the changeover from verbal input during training to written input in the practical application, and the differences caused by having to change to keyboard tasks which require extensive visual control.

It is reasonable to conclude that it may be somewhat irresponsible to opt for any particular system of training when the only criterion used is the output in words per minute.

Translation

In this section we will discuss the step from reading the copy to the operation of the correct keys. The action must be adapted to the stored sequence of letters and to the movements to come (Crossmann 1964). The translation rules that relate stimuli to responses are quite simple in keyboarding. Each stored symbol has to be changed into a typed symbol. Searching for the key will take time, more so the more alternative keys on the keyboard. The time will be reduced, however, by prolonged practising of the letter-key combinations (Mowbray & Rhoades 1959), by the knowledge of highly probable sequences of letters and by making full use of any information which reduces the uncertainty of what happens later in a particular task (Fitts 1959). The long-term storage—the permanent memory—mediates by giving the perceived sequences of letters significance for ensuing action (Welford 1958). From our point of view, however, the most important role in reducing the processing time is played by the degree of S-R Compatibility (Fitts 1959, Fitts-Deiniger 1953). This concept can be made clearer with an example:

When a person has to react to these lights by pressing one of three knobs, then different arrangements of lights and knobs may have different efficiency, according to the compatibility of stimuli and corresponding responses. In keyboarding, we may say in an analog sense that with a given sequence of letters, the sequences of movements can be easier with one keyboard-arrangement than with another. Statements about the best type of display of stimuli or the best type of location of control are often meaningless. It is the joint occurrence of the use of a special stimulus code and a special response code, that have varying degrees of compatibility. The S-R ensemble is usually the important determinant of performance (Fitts 1964) from which an evaluation can be made.

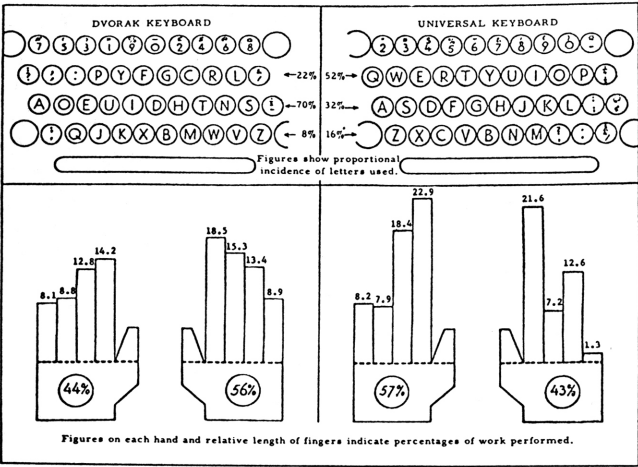


Fig 5 (after Dvorak) Hand and finger typing loads on the New Simplified and the old 'Universal' Typewriter Keyboards

I want to extend the concept of S-R compatibility as it seems to be too mechanistic and does not fully stress the importance of the operator, who has to perceive the stimuli and make the appropriate responses. Fitts (1959) related S-R compatibility to population stereotypes, but this has a mere descriptive and not explanatory meaning. We will propose, therefore, stimulus—operator—response—or S-O-R compatibility. This involves compatibility of input displays and response arrangements, as well as of encoding and decoding channels, while the mediating role of the operator is determined by a number of measurable factors or intervening variables (cf. Tolman 1951):

The extent of the long-term storage, ie the way in which past experience is represented both in range and frequency and the corresponding effect on improvement of performance.

The level of intelligence: the capacity to derive and apply optimal and economical rules for translation. (cf. 'Symbolical control processes', Crossman 1956.)

Physiological limitations set by the sensory and motor systems. In typing, the English language has fixed properties. Higher compatibility would involve variation of the keyboard arrangement and experimentally testing if some combinations turn out to be better than others. For instance, Conrad made a suggestion that a keyboard with, instead of Q.W.E.R.T., A.B.C.D.E. etc., may have greater efficiency in earlier stages of typing. The structures of different languages have to be compared and for each language region an optimal compatible keyboard has to be developed. This implies, apart from adaptability on the side of the manufacturers, intensive basic research as to what principles have to be used in the layout and as to problems of the capacities and preparedness of operators to transfer to the new keyboard layout. Examples of such basic research are the studies by Dvorak, Fox and Stansfield and Kroemer.

Dvorak constructed in the 'thirties a keyboard where the load was more evenly spread over the five fingers, where optimal use was made of the home keys and where the alteration of hands for the successive letters was made more frequent (Dvorak, Merrick, Dealy, Ford, 1934).

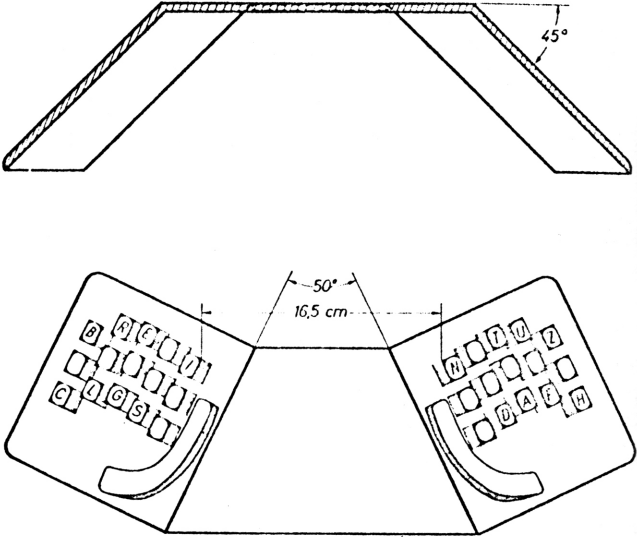


Fig 6 (from Kroemer) Schematic representation of the keyboard as developed by Dr Kroemer at the Max-Planck-Institut in Dortmund, Germany

Fox and Stansfield (1964) measured the rate at which typists keyed two-letter sequences, when typing continuous material at the overall rate of 80 words per minute. They found that keying digrams using alternate hands needed far less time than using the same hands (.09-.11 sec. as compared to .12-.14 sec.).

Kroemer (1965) has developed a new keyboard. Operators make fewer errors on this and there is a significant reduction in the number of complaints of aches and troubles in fingers, hands, wrists and arms, compared with operators working on the traditional keyboard. He arranged the keys in two separate but symmetrical groups, one for each hand. Each group consists of three curved rows of five keys. The form of the curve corresponds to that of the fingers and the possible movements of the individual fingers. The two space-bars for the thumbs are curved as well, which enables the thumbs to strike them from any hand position. The keyboard position is no longer horizontal since tests disclosed that an angle of 30°-45° to the horizontal gives the most comfortable position to the hands and arms.

Decoding

In our analysis of decoding we will again heavily rely on the excellent treatment of skills by Welford in his book, *Ageing and Human Skill*.

The actual pressing of the keys is normally done unconsciously,

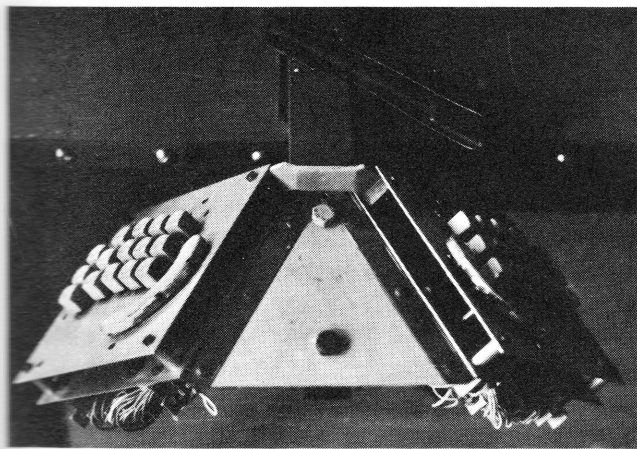


Fig 7 Experimental keyboard as used in tests by Kroemer

but prerequisites for proper functioning are the availability in the operator of an image of what has to be done, of possible methods of typing and the particular dexterities needed.

The movements are more or less organized as a result of the adaptation of each new movement to this past experience and to the requirements of the occasion, while the appearance of rhythm can be seen as a form of organization in time.

According to Bartlett efficiency depends upon the regulation of the flow so that nowhere is there any appearance of hurry or prolonged delay, less checking for correctness of outcome is required, and less time is taken, although the actual speed of movement may not increase.

As a result the typesetter acquires a greater ability to anticipate data and to plan actions ahead. At the same time, the size of his 'unit' of performance increases. Instead of three single movement commands for T, H, and E, there is now a single flow 'the' (cf. Bryan, W. L. & Harter, N. 1899).

When learning becomes very thorough the conscious controlling of the keys seems to disappear. One of the most essential aspects of skilled performance seems to be that the attention can shift to the input display (cf. Leonard 1953) although this only seems to be possible when the actions are of such an accuracy that their outcome is never in doubt, as consciousness is essential when some uncertainty has to be resolved.

The time taken for a single movement is a function of the length of the movement and the width of the target (Fitts 1954).

Crossmann reported the trajectory to be quite accurately exponential. Since the correctness of the trajectory of the moving finger towards the target is continuously controlled—the closer to the target, the more frequent and precise the control—the movement will gradually reduce in speed. With practice, however, and no uncertainty as to the correct trajectory, the movements will become ballistic and, therefore, quicker and the attention can shift towards the input display.

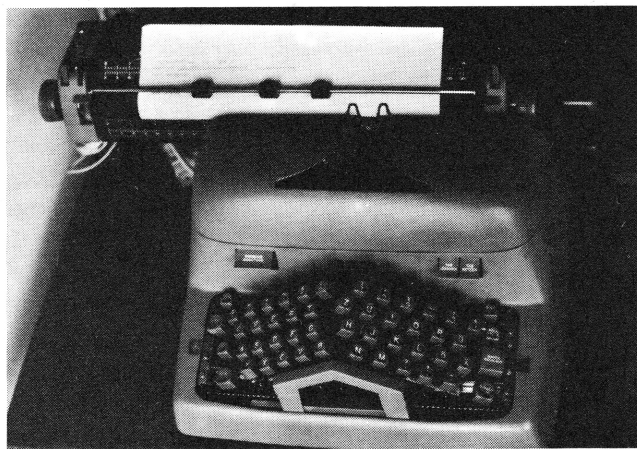


Fig 8 Experimental keyboard incorporated on electrical typewriter as developed by Kroemer. Keys have a slope of $+30^\circ$ with the horizontal, the most comfortable position for the hands

The facilitating role of the long-term storage is analogous to that in encoding. A movement pattern which is to be expected is built up according to the varying sequential frequencies of the letters, so that the hands know, as it were, that once a T is keyed, there are not 26 equiprobable alternatives, but that in 50 per cent of the cases the H has to be struck. On the other hand, every sequence will strengthen, via the proprioceptive senses, the motor memory, a part of the long-term storage.

In keyboarding the ten finger system of blind touch typing is advocated. The actions have to be distributed over the available output channels which have to coordinate in order to release a timed sequence of responses. One finger controls 3 to 6 keys, the positions of which can easily be remembered. Knowledge of the keyboard could be improved further by introducing better separation of the keys (cf. Kroemer 1965) or by adding tactile cues as on the Palantype stenographic keyboard. The extra time for eye-controlled movements towards the correct keys (Crossmann 1964) will reduce to zero and no attentive control for decoding is needed.

A critical problem, however, is what will ultimately limit the typing speed. Every letter requires an action of one of the human output channels and for an average speed of 60 words a minute 6 strokes have to be made every second and this may continue for hours. The following studies are relevant to this:

It is suggested (Hick 1952) that only a limited amount of information can be processed in a certain unit of time by the human operator. The more information is processed, the longer the reaction time becomes. It is unlikely, however, that there will be a definite upper-limit as with increased practice this relation between information and time seems to flatten out (Mowbray & Rhoades 1959).

Searching for the correct keys and the movements between strokes:— On a traditional keyboard there are about 30 letter keys controlled by eight fingers, so each finger has to move constantly and cannot be kept at the same home keys. This may be eliminated by a 'chord' keyboard (cf. Conrad & Longman

1965). The fingers are constantly kept on the same ten home keys. Letters are signalled by pressing a pair of keys, one key with each hand, so the fingers do not have to move from the home keys. They reported a higher proficiency of the chord-keyboard after intensive practice during 28 days, but this may be mainly due to their simple arrangement of the letters, so that the position of each letter was easier to master. A further question is: how accurately can an operator distribute commands and press two fingers at the same moment? (cf. Stockbridge et. al. 1965). A minimal interlock will be necessary to allow for the possible small differences in striking of fingers of different hands. There is, furthermore, less alternation of hands and individual fingers when using such a chord-keyboard.

We feel that some more research has to be done before decisions about keyboard redesign can be made.

Less important problems to be resolved are those such as the optimum pressure required for the keys, the distance between keys, and the positioning of special function keys. On the basis of some observations in the industry (Richard Clay—Bungay) we think it to be extremely useful to ask the assistance of the typesetters themselves, not so much for motivational reasons as that the operators have first hand experience and are professionally interested in such problems.

An aspect of psychology that is most neglected by psychologists is rhythm, the importance of which is always stressed by those with practical experience in typing.

In the perception of visual stimulus configurations there is a kind of structure or pattern which gives considerable redundancy in the set of stimuli present at any moment. In an analogous sense, rhythm may give the redundancy in the proprioceptive sense—modality.

Bartlett (1958) points to the role of rhythm in timing, as the efficiency depends upon the regulation of the flow from component to component in such a way that nowhere in the series is there any appearance of hurry and nowhere unnecessarily prolonged delay. Elsewhere (1947) he notices that fatigue will result in loss of rhythm, but the relation may be reversible as well so that a constant rhythm may prevent fatigue. The latter is probable when we conceive rhythmic behaviour as consisting of two-phase motor units (Woodworth 1958), building blocks of spatially or temporally organized motor sequences, unified and consisting of a preparatory act, followed immediately by the act itself.

The constraint to keep a certain rhythm facilitates the elimination of conscious control and makes the task more automatic so that the action is more accessible for a direct intervention by the long term storage of past experiences. This will reduce as we have seen the uncertainty of response, but also prompts the operator to follow errors in the copy itself.

To illustrate the practical problems which follow from this gap in our knowledge of the effects of rhythm, consider the following example: When we have assessed the varying grades of difficulty for sequential movements on the keyboard: *easy*, with the same

fingers of alternate hands on home keys (G-T), *difficult*, awkward movements of an awkward finger (Z-Q)—and furthermore, when we have found the frequencies of the various digrams in normal English, we could design a new keyboard layout by attaching the easiest movements to the most frequent digram (T-H). This should result in a large volume of very fast movements and a low number of time consuming moves but the rhythm would then be jerky and unbalanced. A better solution might therefore be to associate awkward movements with high frequency digrams and the easier movements with the low frequency digrams since this might result in more or less the same time between all movements and these promote a regular rhythm.

Feedback

We consider feedback to be information of various kinds, that the operator receives about his performance and it also includes the resulting adaptation of his performance (cf. Ammons 1956. Bilodeau 1955).

The striking of the keys and the resulting print out are taken up as input, evaluated against an image of how the action should be done, and corrections are made until no more errors are present.

Fisher (1965, personal communication) made a useful distinction between proximal and distal feedback.

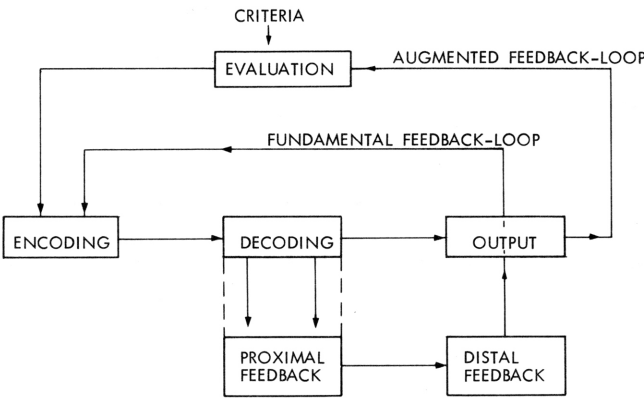


Fig 9 Representation of feedback, distinguishing between proximal, distal and augmented feedback

The proximal feedback or the ‘feeling’ in typing works in a continuous, involuntary and diffuse way. It is mediated by the proprioceptive and non-attentive auditory and visual mechanisms. It functions without time-lag as an undistorted general checking, ie a noting of possible inadequacies in the encoding and decoding activities. It stabilizes the performance by reinforcing the long term storage or the motor memory. In this way, the operator becomes sure of the correctness of his operations and gains confidence. Improvements in performance are reported however (by Chase et. al. 1965) when quickening or proportionally amplifying the relevant error-(or performance-) signals, both with visual and auditory displays. This finding clearly has significance for the end of line control. Fitts attributes the improvements to the effect on discrimination learning.

The distal feedback, being discontinuous, voluntary and precise, checks the diffusely noted errors by attentive inspection and control of the hard copy, the line-length or the total layout. It is mainly mediated by the fully conscious visual attention.

The distal feedback can be augmented by an instructor's evaluation of the results against an external criterion of proficiency. This form of so called *augmented feedback* (Kinkade 1963) is not present in the recently developed techniques of programmed learning, although computer controlled adaptive designs may simulate the role of the personal instructor more and more.

The fact that there is no learning without distal feedback makes us stress the importance of a print-out for operators of below optimal levels of skill. Kinkade (1963) reports that augmented feedback cues as given by the instructors are mediated by the subject primarily as confirmation of adequate or inadequate controlling behaviour. If the fundamental feedback information however is obscured, the operator will utilize augmented feedback, not as supplementary information, but as a substitute for the fundamental feedback signals. The instructor has to realize that feedback signals should be clearly perceptible in the training task and have the same characteristics as those in the operational task for which the training is undertaken.

We have so far seen that the operator has to deal with at least three sources of information, first the normal input or the copy, secondly the mainly proprioceptive feedback during decoding and finally the result of the decoding, that is the print-out, for checking errors and end-of-line decisions. His attention has therefore to be distributed over a variety of controls.

It is suggested (Welford 1959) that a decision mechanism exists associated with conscious attention, which appears to be concerned with the resolution of uncertainty. Full conscious attention can only be given to one event at a time by this single channel mechanism for information and it may well be that this limitation imposes the highest load on to the operator. Higher speed, fewer errors and reduction of fatigue may result from diminishing this load. This can be brought about in a variety of ways:

Increased practice. When a performance is so thoroughly learned that it becomes automatic it can be carried out while leaving the decision mechanism virtually free, as there is no uncertainty left associated with malfunctioning, and the attentive control will become better integrated (Welford 1958). Bahrck, Noble & Fitts observed that, if proprioceptive feedback is increasingly important after extended learning and if less reliance on visual cues is necessary as the learning of the first of a two part task progresses, then a second, say visual task, like controlling the end of line, should have less and less interfering effect on the first task, to the extent that the first task is highly overpractised. We may relieve, for example, by distributing the control over different vision compatible sensory channels. Operators are trained not to watch the keys in blind typing. The end of line can be controlled by a tone increasing in amplitude or pitch. A study will have to be made of the degree of compatibility and efficiency of the different sense modalities, with regard to proximal and distal feedback (Fisher—personal communication).

Increasing feedback, by making discrimination of the feedback-input easier. Studies of quickening and augmenting of feedback (Kinkade 1963; Chase & others 1965) will have to be extended to evaluate the efficiency of the different sense channels.

The total task requirements may be modified. Some examples:

Improving the position of the copy by placing it for instance in focus with the other control displays.

Reduce the auxiliary tasks of various mechanical operations. This auxiliary task may however prevent some operators from boredom.

Make error checking easier and reduce awkward movements when correcting errors in tape.

Eliminate hyphenation and end-of-line decisions by the introduction, say, of computer typesetting.

Within this framework of attention and feedback the problem of whether to use print-out or not has to be studied.

Conclusion

Finally, as an enumeration of the components in keyboarding, we can give the last Fig 10. This depicts the successive actions and processes, the kinds of control required as well as the sense modalities occupied by these control functions.

As the review itself already takes the form of an abstract of the relevant psychological literature, this slide may stand for a more formal summary of this paper.

I hope to have given a schematic review of factors which are involved in the skill of keyboarding. I am aware of limitations in this approach, as the criterion for inclusion in this paper was that an element was both valid and of some importance for all operators. Further studies should deal with environmental influences (lighting—ambient noise, social factors) with the motivation of the operators, with the principles and optimal methods of training and with the interindividual differences related to disposition and age.

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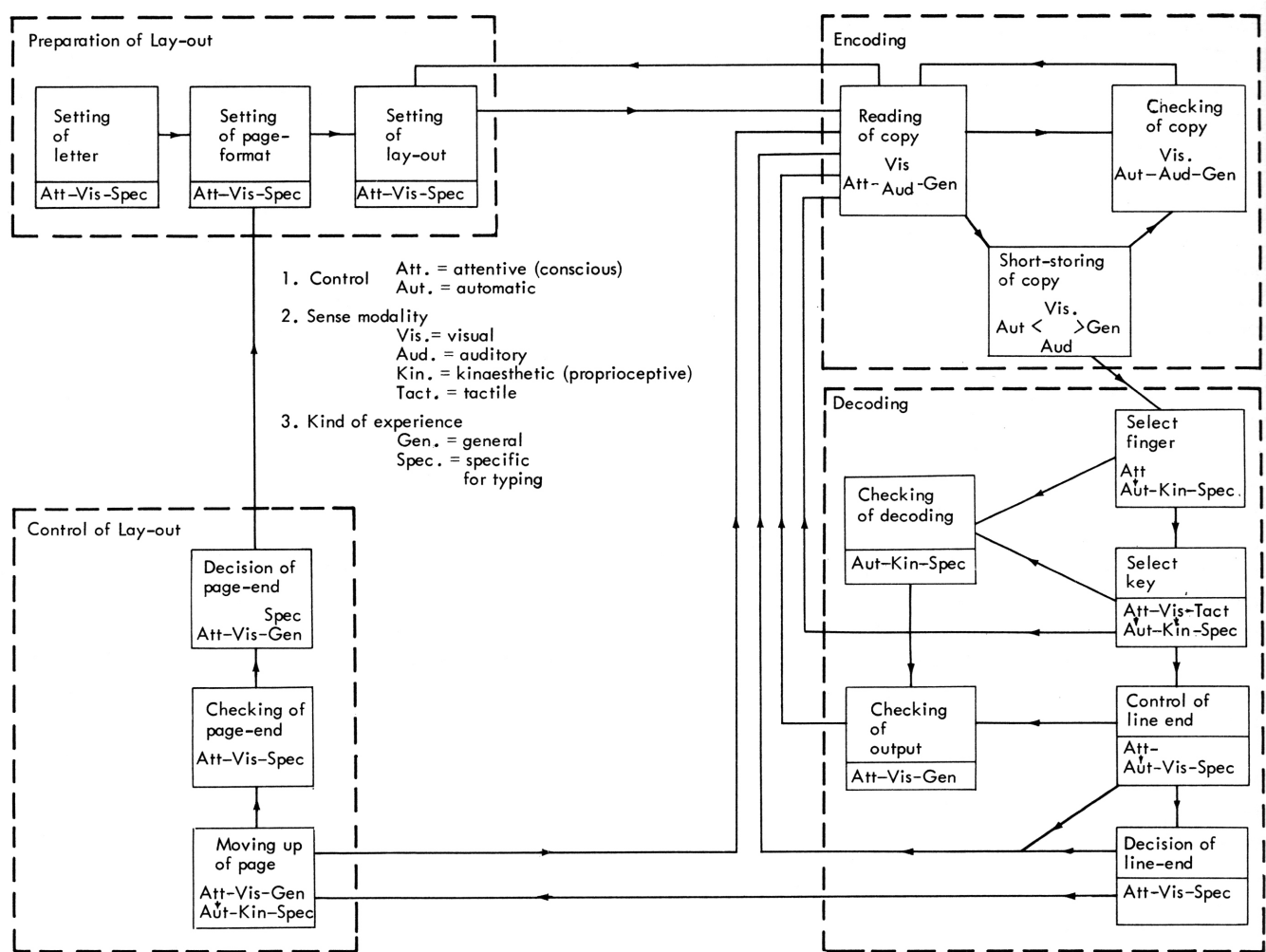


Fig 10 The elements involved in keyboarding represented in a schematic way. Arrows indicate sequences in the process as well as control functions. In the lower part of each block are indicated the kind of control exercised, which sense-modalities are used and whether the required experience is specific for this special skill.

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